BIOMECHANICAL INDICATORS OF KEY ELEMENTS OF SPORTS EQUIPMENT GYMNASTIC EXERCISES

Potop V.A.[1], Grad R. [2], Boloban V.N. [3]
Ecological University of Bucharest[1]
Józef Piłsudski University of Physical Education in Warsaw [2]
National University of Physical Education and Sport of Ukraine[3]

Annotation. The aim of this study is to analyze the biomechanical performance of the kinematic and dynamic structures of key elements of sports techniques of basic exercises performed gymnasts aged 12 - 14 years to the vaulting and on the bars of different heights, on the basis of the method of postural orientation movements. The study involved 11 gymnasts doing exercises on the vaulting and 9 gymnasts - on the boards of various heights. It is shown that the method of video - computer analysis of the type Yurchenko vault and dismount from the bars of varying heights, in conjunction with the method of postural orientation movements possible to isolate and identify the node elements. The indicators characterizing the node elements of sports equipment movements gymnasts in the phase structure of the vault and dismount from the bars of different heights have specific features and characteristics. Learned node elements sports equipment is the basis for the measurement, analysis and evaluation of the kinematic and dynamic structures and other types of exercises all-around gymnastics.
Key words: biomechanics, posture, phase jump, gymnastics.

Introduction

Analysis of scientific-methodic literature witnesses about importance of studying of gymnastics' and acrobatics' techniques and their training considering knowledge about posture and position of sportsman's body. In this connection, for researching gymnastics exercises' technique, V.N. Boloban, Ye. V. Biriuk [1] offered using the method of movements' posture-bench marks. Method of movements' posture-bench marks is the method of bio-mechanical study of sport exercises by means of analysis of preceding and posterior body postures, positions of body and their multiplication in phase structure of executed movement in order to learn key elements of sport technique. Key element of sport technique is a pilot posture of movement, which preconditions effectiveness of movement task's solution by a sportsman. Method of movement's posture-bench marks was developed at the end of seventies. The following years, conception and methodology, scientific-practical application were improved in works by V.N. Boloban (1988 – 2013), as well as in the works by Ye. Sadovskiy, T. Nizhnikovskiy, A. Mastaleg, V. Vishniovskiy, M. Begaylo (2003 – 2013), V. Potop (2012), N. Andreyeva (2013), et al [2,3,6,13,15,17 -20,26,29].

With the help of movements' film-analysis, as well as video-computer program APAS 2000 we carried out bio-mechanical study of key elements of the following exercises' techniques: jump by step; jump by step- jump by step; ball throw in jump "Cossack" – catching in spin on two arms and back in rhythmic steps; ball throw in jump touching into ring - catching in spin on two arms and back in rhythmic steps; forward spin – forward somersault in tuck position; rondat –back somersault in tuck position; rondat - back somersault, sagging; rondat - back double somersault in tuck position; rondat - back double somersault, sagging; rondat - back double somersault, sagging in combination with pace somersault and so on. Then, with the help of method of movements' posture-bench marks authors indentified the following key elements of sport techniques in the listed above exercises: in phase of preparatory movements key element is starting posture of body –position of body bio-mechanically rational for entering main phase of exercise; in phase of main movements key element is multiplication of posture (postures) of body; multiplication of postures (MP), being a key element of sport technique, is regarded as the process of successive fulfillment of instant fixed postures of one profile (e.g. triplex back somersault in tuck position) or combined profile of movements (e.g. triplex back somersault in tuck position with turn by 360 º in first somersault) for creation of integral motion action with controlled change of body postures, body positions; MP determines composition and structure of exercise; in phase of finalizing movements key element is final position of body, which characterizes stability of body on support for completion of exercise or creation of conditions for next combination of exercises.

The conceptual essence of method of movements' posture-bench marks is that every preceding position of body shall positively influence on bio-mechanics of the following posture in exercise, fulfilled by a sportsman that permits to fulfill this exercise without extra motion actions in order not to accumulate technical mistakes when demonstrating exercise or combination of exercises. As an example we supply our written evaluation for exercise on bars executed by Aliya Mustafinova (Russia), champion of OG 2012. She fulfilled highly difficult, highly elegant and beautiful exercise. All movements "fitted" position to position, i.e. all previous and following movements of the exercise were fulfilled technically accurately; the sportswoman used inner energetic potential of movements through effective transmission of properties (power, space and time) of the preceding position to the following one, without accumulating technical mistakes that permitted for the sportswoman to demonstrate exemplary sport technique of revolutions, rotations around longitudinal axis of body, recessions, risings, flights, flights over bar, dismount – double somersault with one and half of pirouettes. [www.youtube.com. Alija Mustafina].

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"Newly coming always desires to follow the previous… And like reasonable disposition of all beings all appearing make not a simple succession, but a certain admirable disposition" – Marcus Aurelius. Reflections. Book forth.

It is very interesting and instructively written in Tai Chi Yuan – martial art and health related gymnastics. For mastering of exercises of this system with high quality disciple shall pass three compulsory stages. "First stage … embedding of foundation … development of correct body position … stability of steps. Second stage … transition to mastering of main postures or final positions and methods of movements from one position to another. Third stage… full understanding of all movements…" [http://dharuma/ru>?p=222. Magazine of Dharuma, 2008.].

Bio-mechanical researches and pedagogic experiments proved purposefulness of method of movements' posture-bench marks as effective method of analysis and evaluation of sport techniques' elements and as a base for development of didactic technologies for training of sports exercises of different coordination complexity [4,5]. In researches [16] there are presented recommendations to use method of movements' posture-bench marks for track and fields running. Authors specify three postures: posture of running, posture of barrier attack and coming from it; in high jumps – running posture, posture of repulsion and posture above bar; in long jumps: running posture (during running and flight by "scissors" method), posture of repulsion starting step and posture of landing. Authors also underline that exactly body posture and reproduction of postures shall be the object of study. Researching elements of structure's elements of track and field sportsmen's technical level V. Gamaliy, M. Ostrovskiy [9, pg.96] write that the process of formation and perfection of exercises' sport technique shall be based not on the principle of rising of bio-mechanical movements characteristics' absolute values, but on studying and formation of mechanisms of their achievement when carrying out competition actions.

In this connection N.G. Suchilin [22,23] points at the fact that every phase of movement contains leading element of coordination, which can be determined on bio-mechanical, physiological and pedagogical levels. Leading coordination element pre-determines development of controlling action in certain phase of movement and gives it specific form and character and determines its structure. It plays trigger role in inter muscular coordination and with maximal forces serves as a mean of increasing of muscular contractions' speed. Correctness or incorrectness of leading coordination element's technique is judged in the base of analysis of control position in the middle of phase, where boundary and leading elements are also determined that permit to substantially order description of sport technique. Phase of technical actions, the author notes, can include even finer components. For example, phase of main flight actions when carrying out double or triplex somersaults in tuck position includes sub-phases of tucking and maintaining tuck position.

Actions by program of body posture is nothing but active unconditioned fundamental principle of realization of full movements' program, quintessence of technique, mean of implementation of the set formal program of position. Just this program component of action-movement is a key and informal part of movement's structure, which shall be mastered in the process of training. "Loco-motor and game kinds of physical exercises – Yu..K. Gaverdovskiy writes – are built, in program respect, mainly as combination of movements – movements of posture and location program. Exercises of synchronized swimming, in their essence, are executed in fixed space zone and are connected, first of all, with movements of posture program and, to less extent, with orientation" [7, pg.259]. Using this approach to analysis of program- kinematic content of exercises in any kind of sports, it is possible to determine more precisely didactic specificity of material and develop, from scientific-methodic positions, approaches to its practical mastering.

Thus, method of movements' posture-bench marks, as a mean of bio-mechanical research of sports exercises by analyzing of previous and following body postures in phase structure of the fulfilled exercise, in order to learn key elements of sport techniques, is effective and is being realized in sport science. It is in the base of bio-mechanical analysis and evaluation of key elements of exercises' technique of sport kinds of gymnastics; it is the base of development of conception of long-term training programs in structure of sports training's macro-methodic [24].

The present work has been fulfilled as per plan of scientific & research works of Ecology University in Bucharest.

Purpose, tasks of the work, material and methods

The purpose of the research is bio-mechanical analysis of kinematic and dynamic structures' indicators of basic exercises' sport technique's key elements, which were fulfilled by 12-14 years old female gymnasts on vaults and bars of different height on the base of method of movements' posture-bench marks.

The tasks of the researches:

1. Identification of key elements of sport technique in phase structure of basic gymnastic exercises, fulfilled by 12-14 years old female gymnasts on vaults and bars of different level on the base of method of movements' posture-bench marks.
2. Bio-mechanical analysis and evaluation of kinematic and dynamic structures' indicators of basic exercises' sport technique's key elements, which were fulfilled by 12-14 years old female gymnasts on vaults and bars of different level.
3. Evaluation of the extent of connection of kinematic and dynamic structures' indicators of basic exercises' sport technique's key elements, which were fulfilled by 12-14 years old female gymnasts on vaults and bars of different level with points received by female gymnasts in individual all-round events and in final at championship 2012 in Rumania.

Methodology and methods of the research:

1. Analysis of scientific-methodic literature.

2. Method of movements' posture-bench marks [1] – analysis of body postures, body positions and their multiplications on support and in space without support in phase structure of basic exercises in vaults and on bars of different height in order to reveal key elements of sport technique and to evaluate time of exercises phase' fulfillment.

3. Video recording of exercises- vaults of Yurchenko type: back somersault, ragging (YuBSR) and back somersault, ragging with turn by 360º (YuBSR 360); dismounts from bars of different level in tuck position; double back somersault in tuck position (DST), double back somersault in tuck position with turn by 360º in first somersault (DST 360 in first), double back somersault, bending (DSB), double back somersault, ragging (DSR) and back somersault, ragging with turn by 720º (SR 720) – was carried out with the help of Panasonic Full HD 3D Camcorder, which was located perpendicular to the plane of movement (sagittal plane). We used program Pinnacle Studio for converting of video record in AVI format, speed of video recording was 30 sh, p. sec; then there was preparation of individual video shots of movement for bio-mechanical computer analysis.

4. Application of computer program «Kinovea» for measuring of joint angle of body's parts in key elements in vaults and with dismounts from bars of different height.

5. Bio-mechanical analysis, with the help of program «Physical ToolKit» for obtaining of kinematic and dynamic characteristics of movements' trajectory of spoetswomen bodies' parts, resulting speed of ankle joint, knee, shoulder, wrist joints and GMC in vaults; resulting GMC power as well as kinematic and dynamic characteristics of rotational movement around apparatus's (pole) axis for preparatory movements of body flight in dismounts from bars of different level.

6. Mathematical statistics with the help of computer program "KyPlot".

Organization of the research

11 female gymnasts, fulfilling exercises in vaults and 9 female gymnasts – performing on bars of different level, from whose 6 persons are reserve of combined gymnastics team of Rumania, took part in the research. The research was carried out in period 25-27.10.2012 in Deva, championship of Rumania in individual all round events and in final by apparatuses. In the article we have presented results of study of key elements of exercises' sport techniques in vaults of Yurchenko type: YuBSR, YuBSR 360 and dismounts from bars of different level: DST, DST 360, DSB, DSR, SR 720.

In tables 1 and 2 we have presented anthropometric and bio-mechanical indicators of female gymnasts for analyzing of vault exercises and exercises on bars of different level with the help of program Physical ToolKit.

Table 1

Anthropometric and bio-mechanical indicators of junior, 12-14 years old, female gymnasts, for analyzing of sport technique of Yurchenko-type vaults (n = 11)

	Names	V	Height *(m)*	Height with raised arms *(m)*	Mass, *(kg)*	IM *(kgm^2)*	RM / GMC, *(m)*		
							Ankle	Shoulder joints	Wrist joint
1	V.K.	YuBSR	1.49	1.90	36.6	81.25	0.75	0.437	0.611
2	Ch.A.	YuBSR	1.44	1.80	36.6	75.89	0.708	0.407	0.592
3	O.A.	YuBSR	1.54	1.92	40.4	95.81	0.757	0.454	0.658
4	O.A.	YuBSR 360	1.54	1.92	40.4	95.81	0.735	0.421	0.528
5	S.Sh.	YuBSR	1.52	1.90	40.4	93.34	0.841	0.441	0.647
6	S.Sh.	YuBSR 360	1.52	1.90	40.4	93.34	0.748	0.448	0.587
7	I.A.	YuBSR	1.38	1.77	32.1	61.13	0.696	0.423	0.535
8	Zh.L.	YuBSR	1.32	1.74	30.1	52.45	0.716	0.40	0.542
9	Zh.L.	YuBSR 360	1.32	1.74	30.1	52.45	0.677	0.349	0.487
10	Z.S.	YuBSR	1.45	1.86	31.5	66.22	0.661	0.394	0.556
11	Z.S.	YuBSR 360	1.45	1.86	31.5	66.22	0.695	0.367	0.518
Mean			1.45	1.85	35.46	75.81	0.73	0.41	0.57
SEM			0.02	0.02	1.35	5.17	0.01	0.01	0.02
SD			0.08	0.07	4.48	17.13	0.05	0.03	005

Legend: V- vaults, YuBSR – Yurchenko's back somersault, ragging, YuBSR 360- Yurchenko's back somersault, ragging, with turn by 360º, IM inertia of movement, RM – radius of movement, GMC- general mass center, Mean – mean mark, SEM – error of mean arithmetics, SD – mean square deviation.

Table 2

Anthropometric and bio-mechanical indicators of junior, 12-14 years old, female gymnasts, for analyzing of sport technique of dismounts from bars of different height (n = 9)

Names	Dismounts	Mass, kg	Height with raised arms, *(m)*	IM kgm^2	RM, *(m)*			
					GMC	Ankle	Knee joints	Shoulder joints
V.A.	DST	34.1	1.88	120.52	1.559	2.089	1.835	1.333
Ch.A.	DST 360°	33.1	1.80	107.24	1.359	1.716	1.564	1.238
P.A	DSB	31.4	1.80	101.74	1.363	1.837	-	1.094
I. A	DSB	32.1	1.77	100.57	1.42	1.892	-	1.151
O.A	DSB	40.4	1.92	148.93	1.345	1.803	-	1.021
M.I.	DSR	41.5	1.91	151.39	1.805	2.219	-	1.584
T.D.	DSB	31.2	1.78	101.71	1.389	1.806	-	1.155
T.P.	DSB	38.5	1.95	146.39	1.314	1.81	-	0.972
S.Sh.	SR 720°	40.4	1.90	145.84	1.48	2.028	-	1.194
Mean		35.86	1.86	124.93	1.45	1.91	1.69	1.19
SED		1.43	0.03	7.62	0.05	0.05	0.14	0.06
SD		4.28	0.07	22.85	0.15	0.16	0.19	0.18

Legend: DST - double back somersault in tuck position; DST 360°- double back somersault in tuck position with turn by 360º in first somersault; DSB - double back somersault, bending; DSR - double back somersault, ragging; SR 720°- back somersault, ragging with turn by 720º.

Results of the research

On the base of bio-mechanical analysis of gymnastic vault exercises of Yurchenko type – the following key elements of sport technique were indentified: starting position of body (SPB1) – position of gymnast's body in stand on jumping off place before back flight in half of turn; SPB2 – position of gymnast's body in stand on hands, supporting on gymnastic table before one and half back somersault, ragging flight and one and half back somersault, ragging, with turn by 360 degrees; multiplication (MP1) of spring-rigid body posture, straighten in first flight with raised and deflected a little backward arms in back half-turn after repulsion from springboard; multiplication (MP2) of sportswomen's body posture in pain phase of exercise of second flight, after repulsion from gymnastic table (somersault, ragging, and somersault, ragging, with turn by 360 degrees); finalizing body posture (FP) in phase of finalizing movements – landing (key element, which characterizes stable landing of vaults is half-squatting with forward half bent of body in narrow stand with feet apart, arms stretched forward and apart as well).

Besides, key elements of sport technique of exercises on bars of different level (dismounts) were also indentified: double back somersault in tuck position, double back somersault in tuck position with turn by 360 degrees in first somersault, double back somersault, bending, double back somersault, ragging, back somersault, ragging with turn by 720 degrees. It was found that phase of preparatory movements consists of two sub-phases: first – passing under lower bar (PP1) and completion of big back rotation with insignificant deceleration of thighs (second sub-phase – PP2) – this body position is determined as PP –i.e. the most rational gymnast's body position for entering in main phase of dismount (with dismount – back somersault, ragging, with turn by 720 degrees in second sub-phase – PP2 – is registered for more long time; with it speed of legs' movement is less); MP – multiplication of body posture, with which maximal speed of GMC flight is demonstrated in dismounts and exercises' fulfillment with some technical errors of body posture's control; FP – finalizing posture – landing (key elements, which characterize stability landing from bars of different level, is half-squatting with forward half bent of body in narrow stand with feet apart, arms stretched forward and apart as well).

Bio-mechanical analysis of key elements of Yurchenko's vaults' sport technique, which are characterized by joint angles' indicators in PP1, PP2. MP1. MP2 and FP are given in table 3 and in fig 1.

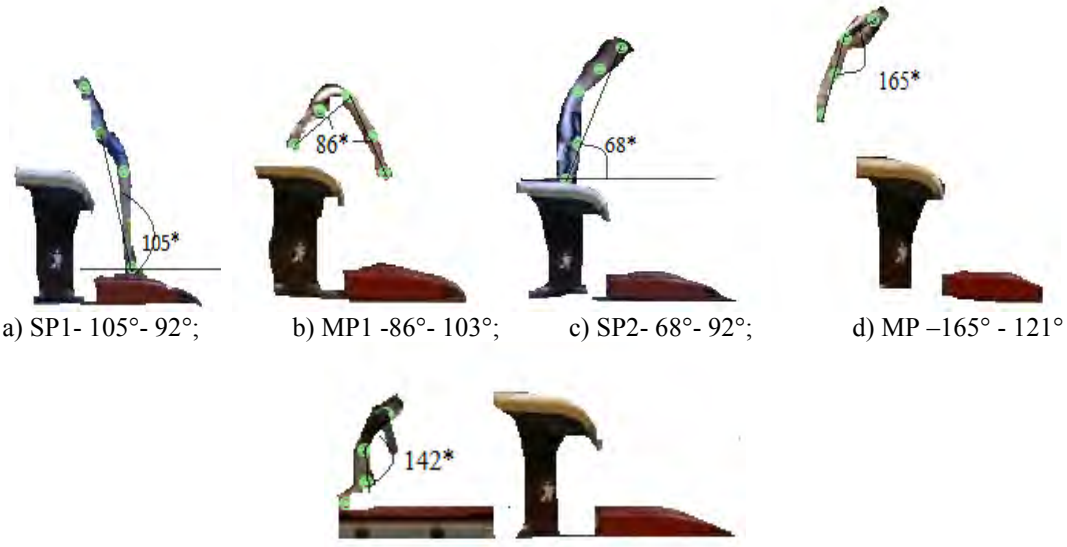
Table 3

Indicators, which characterize kinematic structure of key elements of Yurchenko's vaults' sport technique by data of joints' angles of junior, 12-14 years old, female gymnasts, who participated in sSport gymnastics championship 2012, Rumania.. (n = 11)

	Name.	Vaults	SP1*(degrees)*	MP1 *(degrees)*	SP2 *(degrees.)*	MP2 *(degrees)*	FP *(degrees)*
1	V.K.	YuBSR	93	98	92	135	152
2	Ch.A.	YuBSR	100	87	84	130	129
3	O.A.	YuBSR	101	90	82	135	136
4	O.A.	YuBSR 360º	96	87	68	159	84
5	S.Sh.	YuBSR	94	87	81	143	117
6	S.Sh.	YuBSR 360°	98	86	83	165	83
7	I.A.	YuBSR	105	103	80	121	96

8	Zh.L	YuBSR	98	93	83	142	142
9	Zh.L.	YuBSR 360°	95	98	82	160	95
10	Z.S.	YuBSR	92	92	82	130	138
11	Z.S.	YuBSR 360°	98	91	84	142	129
Mean			97.27	92.00	81.91	142.00	118.27
SED			1.15	1.17	1.68	4.23	7.44
SD			3.82	5.57	5.57	14.04	24.68

Legend: SP1- starting posture – body position in stand: feet on jumping off place before repulsion – angle of ankle – shoulder joints; MP1 – elastic-rigid posture with insignificant ragging and raised arms, a little deflected backward to the floor in back half turn after repulsion from jumping off place – angle of ankle – shoulder joints; SP2 gymnast's body position for flight after resting on apparatus – angle of wrist- knee joints; MP2 - multiplication of postures – maximal height of GMC – angle: thigh – body; FP – final posture, angle: thigh-body – landing; Mean – mean mark; SEM – error of mean arithmetic value; SD square deviation.



a) SP1- 105°- 92°; b) MP1 -86°- 103°; c) SP2- 68°- 92°; d) MP –165° - 121°

e) FP – 142°-83°

Fig.1. Indicators of joints' angles of Yurchenko's vaults' sports technique's key elements

Analysis of individual indicators of kinematic structure of sport technique's key elements in vaults of Yurchenko type by data of joints' angles (with the help of program «Kinovea») of junior, 12-14 years old female gymnasts – participants of gymnastics championship 2012, Rumania, witness that every sportswoman has own characteristics of joints' angles of key elements and every key element has close to optimal joint angle and even convenient sector of space (see table 2 and table 3): SP1 [92°-105°]; MP1 [86° – 103°]; SP2 [68°-92°]; MP2 [121°- 165°]; FP [83° – 152°].

In table 4 and fig 2 indicators of space-time characteristics of key elements' technique of vaults of Yurchenko type are given by the data of movements' trajectory of junior female gymnast S.Sh., 14 years old, which were fulfilled on sport gymnastics championship 2012 in Romania.

Table 4

Indicators of space-time characteristics of key elements' technique of vaults of Yurchenko type by the data of joints movements' trajectory of junior female gymnast S.Sh., 14 years old, which were fulfilled on sport gymnastics championship 2012 in Romania.

Key elements	Vaults	TKE *(sec.)*	GMC*(m)*		Ankle *(m)*		Shoulder joint. *(m)*		Wrist joint *(м)*	
			X	Y	X	Y	X	Y	X	Y
SP1	YuBSR	0.1	1.15	1.085	1.018	0.317	0.952	1.468	0.846	1.97
	YuBSR 360°	0.133	1.004	1.121	1.043	0.313	0.834	1.551	0.548	1.903
MP2	YuBSR	0.167	0.82	1.653	1.058	1.031	0.331	1.626	-0.013	1.362
	YuBSR 360°	0.2	0.639	1.747	1.095	1.082	0.222	1.656	-0.081	1.291
SP2	YuBSR	0.233	0.172	2.142	0.648	2.631	0.013	1.732	-0.053	1.283
	YuBSR 360°	0.3	-0.13	2.255	0.091	2.985	-0.104	1.799	-0.156	1.395
MP2- MFH	YuBSR	0.367	-0.595	2.38	-1.124	1.957	-0.119	2.446	-0.37	2.208

	YuBSR 360°	0.4	-0.73	2.347	-1.577	2.112	-0.326	2.399	-0.365	2.438
FP	YuBSR	0.667	-2.089	0.808	-2.063	0.304	-1.798	1.111	-1.547	0.833
	YuBSR 360°	0.7	-2.539	0.837	-2.565	0.332	-2.113	0.997	-2.242	0.713

Legend: x – horizontal movement;, y – vertical movement; MFH – maximal height of second flight of vault;, TKE – time of key elements' fulfillment;

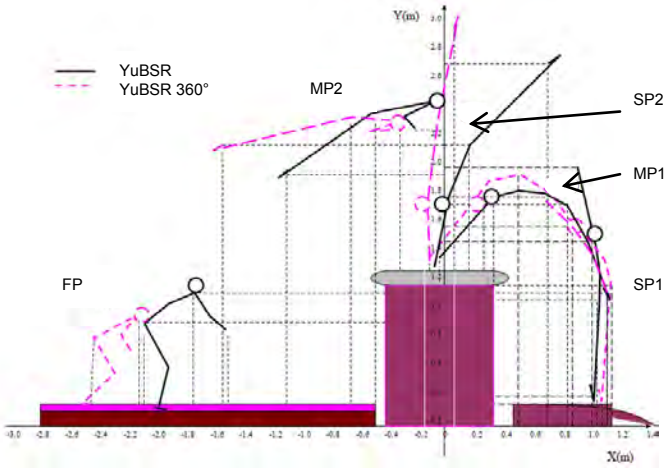


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Fig.2. Key elements of Yurchenko's valuts' sport technique: YuBSR, YuBSR 360°. The tested: junior female gymnast, 14 years old, S.Sh., champion of Rumania in vaults.

Results of comparative analysis of space-time characteristics' indicators of Yourchenko's vaults' key elements by the data of joints movements' trajectory of the tested S.Sh. show that time of analysis of vault YuBSR 360° is longer by1video frame. In YuBSR 360° jump, with fulfillment of starting position SP1, position of body has greater bent before repulsion from jumping off place than in YuBSR (angle shoulder- shin = 98°); multiplication of posture (MP1) is longer and higher in back half-turn – GMC = 1.747m; starting posture SP2: there is no deceleration of legs in supporting curvet (from stand on hands) – angle = 83°; multiplication of posture (MP2) – flight in second phase of jump was fulfilled with greater bent backward and lower (GMC= 2.347m), bending in hip joints was registered in MP2 that is a technical mistake; final posture (FP) – distant landing -2.565m, with significant forward bent of body.

In table 5 and in fig 3 we present indicators of resulting GMC power, angle speed of parts of S.Sh.'s body in vaults of Yurchenko type.

Table 5

Indicators of resulting GMC power, angle speed of parts of S.Sh.'s body, 14 year old, in vaults of Yurchenko type.

Key elements	Vaults	TKE *(sec.)*	GMC	Ankle joint.	Shoulder joint	Wrist joint
			F, N	Omega, rad/s	Omega, rad/s	Omega, rad/s
SP1	YuBSR	0.1	5010	10.548	33.926	35.384
	YuBSR 360°	0.133	5930	7.892	17.843	26.621
MP1	YuBSR	0.167	3620	6.578	28.097	33.1
	YuBSR 360°	0.2	2480	18.817	15.243	12.206
SP2	YuBSR	0.233	4810	42.374	21.018	13.722
	YuBSR 360°	0.3	1570	19.887	13.761	6.309
MP2- MFH	YuBSR	0.367	5770	35.52	31.622	29.865
	YuBSR 360°	0.4	3160	18.143	16.988	25.218
FP	YuBSR	0.6	650	10.915	18.874	22.051
	YuBSR 360°	0.633	476	23.607	28.229	27.947

Legend*:* see table 1 and 3, F –force, Omega – angle speed.

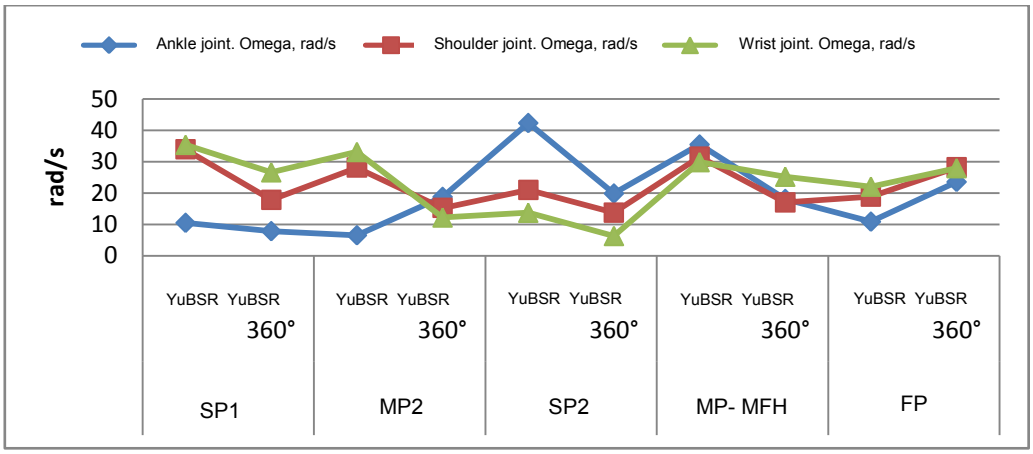


Fig.2. Angle speed of body parts of 14 years old female gymnast S. Sh. In vaults of Yurchenko type.

During fulfillment of SP1 we registered significant resulting GMC force in vault YuBSR 360° - 5930N and less angle speed in ankle, shoulder and wrist joints (7.89 m.p.sec. - 26.6 m.p.sec.); slower jump on springboard was fulfilled; in MP1 – in back half-of-turn – resulting GMC force was 2480N, angle speed in ankle joints was 18.82 m.p.sec., which did not permit for gymnast to effectively control curvet part of SP2; key element of MP2 – maximal flight height of GMC has less resulting force - - 3160N and angle speed in joints (16.9 – 25.2 m.p.sec.), that do not facilitate effective finalizing of rotation in somersault with taking convenient for landing final posture of body (FP)- (result – forward bent of torso and shoulders , lower than technical norm, determined by ФИЖ).

Results of vaults, executed by junior, 12-14 years old, female gymnasts at sport gymnastics championship in Rumania, 2012, in individual all round events and in finals by apparatuses are given in table 6.

Table 6

Results of vaults, executed by junior, 12-14 years old, female gymnasts at sport gymnastics championship in Rumania, 2012 (n =7)

№/№	Names	All round events			Finals, apparatuses	
		Comp.	Ex.	F.M.	Result	Place
1	V.K.	4.400	9.100	13.500	13.088	5
2	Ch.A.	4.400	8.775	13.175	13.075	6
3	O.A.	5.000	9.100	14.100	13.500	3
4	S.Sh.	5.000	8.800	13.800	13.562	1
5	I.A.	4.400	8.800	13.200	-	-
6	Zh.L.	5.000	9.000	13.900	13.387	4
7	Z.S.	5.000	8.800	13.800	13.537	2
Mean		4.74	8.91	13.64	13.36	
SEM		0.12	0.06	0.13	0.09	
SD		0.32	0.14	0.35	0.22	

Legend: (see table 1): Comp. – complexity of vaults; Ex. – points for execution; F.M. – final mark.

Two types of Yurchenko's vaults were executed: YuBSR and YuBSR 360°, complexity of vaults 4.400 points and 5.000 points accordingly; mean mark for execution – 8.91 points; final mark in individual all round events– 13.64 points; finals by apparatuses – mean mark of two vaults – 13.36 points. Analysis showed that junior gymnasts land on springboard insufficiently springing-rigidly after rondat and owing to this fact AP1 for moving by back half-of-turn is fulfilled too slowly, with some technical mistakes, like repulsion by half-bent legs, imprecisely raised arms. These make difficulties for fulfillment of following key elements in phase structure of vault. In particular it worsens opportunities for fulfillment of SP2, MP2, FP, i.e. rotation speed in somersault reduces, that results in not high flight after repulsion from table by hands and inactive raising of torso at beginning of MP2, i.e. more high entering somersault; as a result – too distant flight of gymnast in finalizing phase of vault, final body posture – landing are fulfilled with mistakes.

Results of bio-mechanical analysis of body parts' trajectories as well as GMC resulting force indicators and angle speeds of 12-14 years old gymnasts' body parts, when fulfilling dismounts from bars of different height, are presented in table 7 and 8 and in fig. 4.

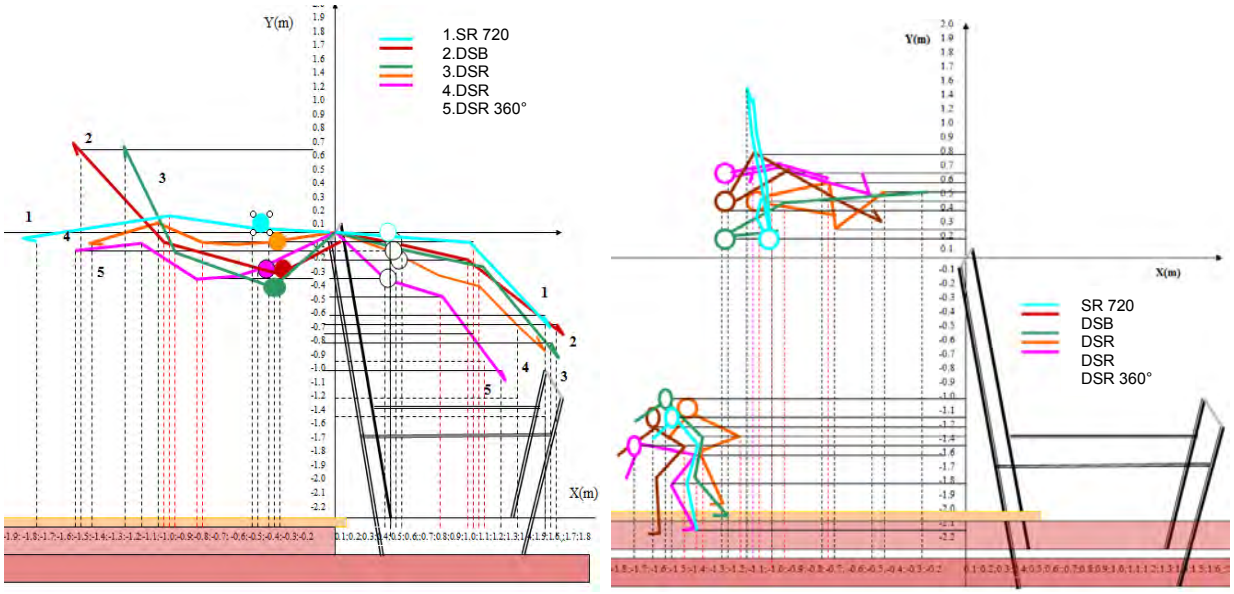
Table 7

Indicators, characterizing kinematic structure of key elements of dismounts from bars of different height sport technique as per data of joints' angles of the tested – junior female gymnasts of 12-14 years old, who fulfilled these dismounts at sport gymnastics championship 2012 in Rumania. (n = 5)

Key elements		Dismount	Names	Torso-thigh (degrees)	Arms- torso (degrees
PM	SPh1	DST	B.A.	147	
		DST 360°	Ch.A.	160	
		DSB	I.A.	158	
		DSR	M.I.	153	
		SR 720°	S.Sh.	132	
	SPh2-SP	DST	B.A.	129	143
		DST 360°	Ch.A.	124	144
		DSB	I.A.	112	143
		DSR	M.I.	143	117
		SR 720°	S.Sh.	210	173
MP - MFH		DST	B.A.	87	
		DST 360°	Ch.A.	100; 93	
		DSB	I.A.	75	
		DSR	M.I.	141	
		SR 720°	S.Sh.	151	
FP		DST	B.A.	94	
		DST 360°	Ch.A.	70	
		DSB	I.A.	111	
		DSR	M.I.	117	
		SR720°	S.Sh.	127	

Legend: PM –preparatory movements; SPh1 – first sub-phase in preparatory movements for dismounts, SPh2 – second sub-phase, transition into SP of dismounts; MP and MFH – multiplication of postures – maximal flight height of GMC; FP – final position of body with landing.

Analysis of sport techniques' key elements' kinematic structure of dismounts from bars of different level, which were fulfilled by tested junior, 12-14 years old, female gymnasts at sport gymnastic championship 2012, Rumania and were registered with the help of program «Kinovea», witnesses that every sportswoman had individual characteristics of joint angles of key elements' sport technique; besides, all key elements had mean indicator of joint angle, own sector of space, in which there is optimal joint angle and interval of angles' indicators (see table 7): SPh1 [132°-160°], SPh2-SP [112° – 210°], torso- arms [117º-173º], MP – MFH [75°-100°], FP [70°–127°]. Characteristics of key element's joint angles and technical mistakes (e.g. in dismount SR 720 angle thigh – torso is 210º at the moment of leaving bar) determine kinematic structure of dismount (see fig. 4). For example, significant ragging of tested S. Sh.'s lumbar spine in dismount SR 720 dis-coordinates system of movements, required for gymnast's entering in pirouette rotation. One more mistake. Concerning other gymnast- Ch. A.: there was registered uncompleted 360 degrees' rotation in first somersault in dismount DSR 360, however in MP she reached maximal height of GMC raising; combined rotation around longitudinal and front (cross) axes in tuck position was fulfilled also with technical mistakes ("broken" tuck position); FP- landing in dismount DSR 360 was carried out with torso forward bent, in unstable manner.



a) PM: SPh1, SPh2 – SP b) MP – MFH, FP

Fig.4 Key elements of dismounts from bars of different height sport technique. Abbreviated names of dismount and gymnast:
DSR – B.A.; DSR 360° - Ch.A.; DSB – I. .A.; DSR – M. I.; SR 720 - S. Sh.

Let us regard indicators of space-time characteristics of key elements' sport technique of dismounts from bars of different height, by the data of join movements' trajectories of tested 12-14 years old female gymnasts, who participated in sport gymnastic championship 2012, Rumania. These data will ring us nearer to understanding the importance of analysis, evaluation and registration of sport technique's key elements' indicators in phase structure of junior sportswomen's movements. For profound study of body postures, positions and their multiplications in structure of key elements of sport techniques of dismounts from bars of different level, analysis of video-materials was divided into two parts: first part – sub phase of PM (SP) was calibrated every 5 video frames, the second part- other gymnasts' movements, were calibrated every 3 video frames (see table 8).

Table 8

Indicators of space-time characteristics of sports technique's key elements of dismounts from bars of different height by data of joint movements' trajectories of tested junior, 12-14 years old, female gymnasts, who fulfilled them at championship 2012, Rumania
(n = 5)

Key elements		Dismount	MTKE *(sec.)*	GMC*(m)*		Ankle joint. *(m)*		Knee joint. *(m)*		Shoulder joint. *(m)*	
				X	Y	X	Y	X	Y	X	Y
PM	SPh1	DST	0.133	1.117	-0.393	1.525	-0.798	1.387	-0.62	0.514	-0.16
		DST 360°	0.133	0.812	-0.537	1.212	-1.012	1.025	-0.775	0.487	-0.325
		DSB	0.167	1.05	-0.231	1.637	-0.694	-	-	0.498	-0.142
		DSR	0.1	1.125	-0.313	1.623	-0.867	-	-	0.535	-0.111
		SR 720°	0.133	1.084	-0.052	1.573	-0.612	-	-	0.507	-0.052
	SPh2-SP	DST	0.033	-0.829	-0.125	-1.439	-0.078	-1.095	0.109	-0.453	-0.125
		DST 360°	0.033	-0.899	-0.362	-1.551	-0.174	-1.145	-0.159	-0.536	-0.29
		DSB	0.033	-1.07	-0.054	-1.534	0.624	-	-	-0.392	-0.357
		DSR	0.033	-0.978	-0.078	-1.226	0.574	-	-	-0.466	-0.404
		SR 720°	0.033	-1.029	0.158	-1.773	-0.032	-	-	-0.586	0.032
MP- MFH		DST	0.133	-0.782	*0.532*	-0.438	0.5	-0.735	0.266	-1.188	0.469
		DST 360°	0.167	-1.044	*0.652*	-0.522	0.478	-0.739	0.681	-1.218	0.638
		DSB	0.133	-1.124	0.767	-0.475	0.232	-	-	-1.32	0.392
		DSR	0.1	-0.947	*0.404*	-0.248	0.497	-	-	-1.273	0.186
		SR 720°	0.133	-1.108	*0.475*	-1.224	1.44	-	-	-1.029	0.063
FP		DST	0.4	-1.204	-1.392	*-1.251*	-1.845	-1.423	-1.595	-1.486	-1.126
		DST	0.4	-1.406	-1.609	*-1.406*	-2.131	-1.508	-1.812	-1.711	-1.421

	360°									
	DSB	0.4	-1.445	-1.623	-1.605	-2.248	-	-	-1.641	-1.302
	DSR	0.4	-1.397	-1.381	*-1.257*	-1.956	-	-	-1.599	-1.04
	SR 720°	0.367	-1.425	-1.488	*-1.472*	-1.963	-	-	-1.636	-1.172

Legend: (see tables 2 and 7). Abbreviated names of dismounts and gymnasts:
DST – B. A.; DST 360° - Ch. A.; DSB – I. .A.; DSR – M. I.; SR 720°- S. Sh.

In table 8 there are presented individual indicators of key elements' sport technique's kinematic structure of dismounts from bars of different level. Key element – SP – is realized in PM phase and contains two sub-phases of movement SPh1 and SPh2 – the moment of passing under lower bar and the moment before leaving upper bar. Position of body and movements in shoulder and hip joints at the moment of passing under lower bar and before leaving upper bar have individual style of fulfillment, different pace-rhythmic structure and space-time indicators. However, in all, analyzed by us, dismounts time of key element's (SP – in Sph2) fulfillment equals to 0, 033sec. The moment of leaving of upper bar is quick and the same by time, while length and height of GMC and parts of body flight (vertical movements (X) and horizontal (Y)) with fulfillment of MP and FP are different, which witness that bio-mechanics of dismounts is complex and structurally different; more over dismounts were fulfilled with technical mistakes of body positions' regulation and body positions in key elements of exercises phase structure.

On fig. 5 there are given indicators of angle speed of body parts (phase of preparatory movements) of 12-14 years old female gymnasts in dismounts from bars of different level.

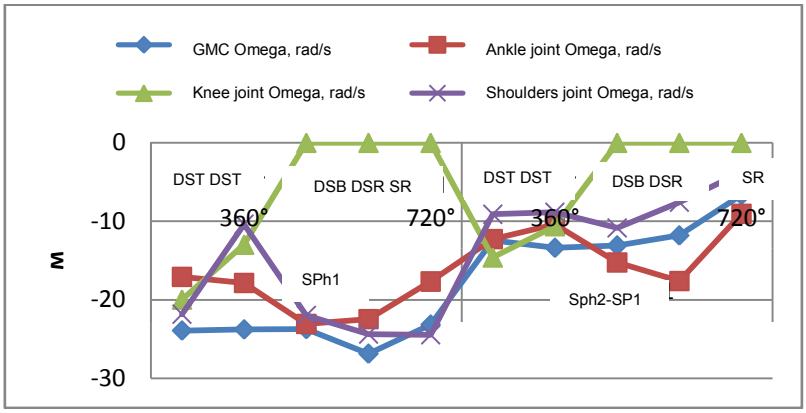


Fig.5. Angle speed of body parts in phase of preparatory movements (PM) of 12-14 years old female gymnasts in dismounts from bars of different level (n = 5)

Analysis of individual indicators of sport techniques' key elements' kinematic structure of dismounts from bars of different level, 9in group dynamics, n=5) witnesses about their variability. For example, in phase PM (SP), in SPh1 angle speed of body parts in DSR dismount had the following indicators: GMC - 26.849 m.p.sec. ankle joints 22.44m.p.sec., shoulder joints - 24.338 m.p.sec. In dismount SR 720 – SPh2 – moment before leaving of bar, there was registered reduction of angle speed for fulfilling of accelerated body rotation around longitudinal axis. Angle speed of rotation around frontal (cross) axis was also reduced: GMS – 6.643 m.p.sec., ankle joint - 9.041 m.p.sec., shoulder joints.- 3.749 m.p.sec.) In key element MP – maximal height of flight in every dismount has its own kinematic characteristics, including different angle speed in joints: GMC in dismounts DST, DST 360º and SR 720º has positive low speed and in dismounts DSB and DSR – negative high speed. In key element FP (DSR dismount) for fixation of stable landing gymnasts had to have high GMC angle speed - 7.814 rad.p. sec. WE also studied dynamic indicators of GMC and parts of body. It was evident that movements' system of junior gymnasts needs physical potential, which would ensure solution of dismount movements' task in compliance with standards of sport technique. One more scientific fact was also evident: need in active didactic work of coaches on training of female gymnasts for them to fulfill technically correct body postures and positions in phase structure of sport gymnastics' exercises (see table 9).

Table 9

Results of junior, 12-14 years old, female gymnasts' performances on bars of different level at championship 2012, in Rumania (n = 9)

Names	Individual all round events			Finals, apparatuses	
	Comp.	Ex.	FM	Result	Place
V. A.	4.500	8.500	13.000	12.725	4
Ch. A.	4.800	6.775	11.575	-	-
P. A.	3.600	8.575	12.175	11.075	8
I. A.	5.300	8.900	14.200	13.125	2
O. A.	5.100	8.550	13.650	12.600	5
M. I.	4.400	8.275	12.675	11.125	7
T. D.	4.800	7.425	12.225	12.125	6

T. P.	5.100	8.525	13.625	13.100	3
S. Sh.	5.000	8.450	13.450	13.500	1
Mean	4.73	8.22	12.95	12.42	
SEM	0.17	0.22	0.28	0.32	
SD	0.51	0.67	0.86	0.91	

In table 9 there are presented results of junior female gymnasts performances at championship of Rumanis in individual all round events and final on bars of different level; in table 10 there are given mathematical dependences of bio-mechanical indicators of kinematic and dynamic structures of exercises' key elements, fulfilled by 12-14 years old female gymnasts in vaults and on bars of different level as well as marks, received by them for individual all round events and in final on apparatuses at championship of Rumania, 2012 (complexity of exercise – 4.73 points, execution of exercise – 8.22 points, final mark – 12.95 points and 12.42 points – final mark for competition on apparatuses).

Table 10

Degree of connection of kinematic and dynamic structures of key elements' structures, fulfilled by 12-14 years old female gymnasts in vaults and on bars of different level with gymnasts' marks for individual all round events and in final on apparatuses at championship of Rumania, 2012 2012 года (n= 16)

Statistical indicators*	Vaults		Bars of different level	
	RF GMC (N) – AS ankle (rad/s) - RARE(points)	RF GMC (N) – AS Ankle (rad/s) – FRA (points)	RF Ankle. (N) – AS Ankle (rad/s) – RARE (points)	RF Гол. (N) – AS Ankle (rad/s) –FRA (points)
t(0) – Cont. correct. t0 <=2	3.37; P <0.001	3.19; P <0.01	4.21; P <0.001	4.04; P <0.001
t - Cont. correct. t0 >2	3.42; P <0.001	3.25; P <0.01	4.24; P <0.001	4.06; P <0.001

Legend: *Wilcoxon Rank Sum Test (Mann-Whitney U Test) for Unpaired Data; RF GMC - resulting force of GMC; AS ankle – angle speed of ankle joint; RARE – results of individual all round events;; FRA final's results on apparatuses.

Conclusions:

1. Method of video-computer analysis of Yurchenko's type vaults and dismounts from bars of different level in combination with method of movements' posture-bench marks [1-4] permitted to mark out and identify key elements, studying of which makes understanding of gymnastic exercises' sport technique deeper and permit to develop up-to-date programs of their training [4,5,13,20]. Conceptual essence of method of movements' posture-bench marks is in the fact that every preceding position of body in fulfilled by sportsman exercise, shall positively influence on bio-mechanic of next posture that permits to execute exercise without extra motion reconstructions in order not to accumulate technical mistakes in the process of exercise's or combination of exercises' demonstration.

2. Vaults of Yurchenko type. Key elements of sport techniques: starting posture of body- one (SP1) – straighten position of sportswoman's body (with slight throatic spine ragging) on springboard before back half-of turn flight; starting posture – two (SP2) - straighten position of sportswoman's body in stand on hands with rest on gymnastic table before back half and one somersault, ragging, with turn by 360º; key element of body posture's multiplication – one (MP1) – spring-rigid, controlled posture of straightened body, ragging in first flight with raised upward arms, slightly deflected backward in back half-of turn after repulsion from springboard; multiplication –two- (MP2) in main phase of second flight, after repulsion from gymnastic table by arms (ragging and ragging with turn by 360º); key element final body posture (FP) in the phase of finalizing movements – is posture of landing.

3. Dismounts from bars of different level. The following key elements were marked out with fulfillment of double somersault in tuck position, back double somersault in tuck position with turn by 360 degrees, in first somersault, back double somersault bending, back double somersault, ragging, back double somersault, ragging, with turn by 720º: in phase of preparatory movements – starting position of body (SP), which consists of two sub-phases: first – passing under lower bar (SPh1) and the second sub-phase, main – completion of big back turn (SPh2), taking of rational body position for effecting removal from bar and entering into main phase of dismount (see fig. 4, a): 1-5); in phase of main movements there were marked out: multiplication of posture (postures) of body (MP), which determines content and structure of exercise in phase of finalizing movements; final body position (FP)- landing (half – squatting with forward torso half-bending in narrow position with feet apart and arms raised upward and also apart). Indicators, which characterize key elements of sport technique of female gymnasts' movements in phase structure of vaults and dismounts from bars of different level, have individual peculiarities and characteristic features.

4. The studied by us, with the help of modern means of research, key elements of sport technique in phase structure of Yurchenko's vaults and dismounts from bars of different level, which were fulfilled by junior female gymnasts, who are the immediate reserve of Rumanian combined sport gymnastics team, and their objective indicators are the basis for measuring, analysis and evaluation of kinematic and dynamic structures and other exercises of gymnastic all round events, for development of programs, devoted to training of preceding and following body postures, bio-mechanically rational transmitting of optimal power, space, time and other movements' parameters and indicators in phase structure of gymnastic exercise.

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Information about the authors:

Potop V.A.: vladimir_potop@yahoo.com; Ecological University of Bucharest; Bd.Milea Vasile nr.1G, Sector 6, 061341, Bucharest, Rumania

Grad R.: bwz@awf.edu.pl; Józef Piłsudski University of Physical Education in Warsaw; 34 Marymoncka Str; P.O.Box 55, 00-978 Warsaw 45; Poland

Boloban V. M.: wboloban@ukr.net; National University of Physical Education and Sport of Ukraine; Fizkultury str. 1, Kiev, 03680, Ukraine.

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